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(54) Title: METHOD AND APPARATUS FOR RADIOFREQUENCY IDENTIFICATION TAGS
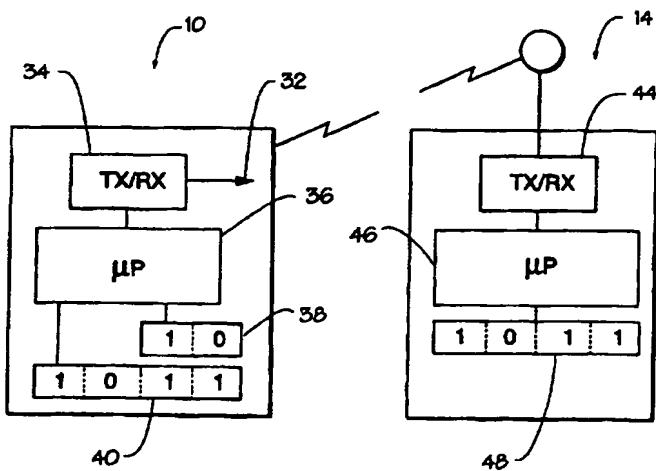
(57) Abstract

A method and apparatus for determining the identification number or any other information within a plurality of radio frequency tags (10) within a common field of interrogation (12) utilizes a combination of an isolated state into which the tags (10) may be placed together with bitwise interrogation of the identification number or information followed by selective deactivation. A first bit in the identification number or information is interrogated of all tags (10) in the field (12). If any tag (10) responds that the bit is a 1, a 1 is entered into an ID register (48) in a reader (14) and all tags (10) in which a 0 exits in that bit position are deactivated. The process continues until only one tag remains activated. The last activated tag (10) at this point has been completely read and is then placed in an isolated state. The process is begun anew with the remaining nonisolated tags (10) until all tags have been read.

METHOD AND APPARATUS FOR RADIOFREQUENCY IDENTIFICATION TAGS

Background of the Invention

5   *1.   Field of the Invention*

The invention relates to the field of radiofrequency identification (RF/ID) tags, and in particular, it relates to methods and apparatus for identification of individual RF/ID tags when multiple tags are present.

10   *2.   Description of the Prior Art*

RF/ID tags may conflict with one another when responding to a single RF/ID reader since the tags are transmitting on the same frequency within the same time slot. A single request to read multiple tags in a field of interrogation can be expected to generate multiple responses which the reader will be unable to separate or differentiate. Therefore, 15 systems in which individual tags use common time frames and frequencies prohibit the use of more than two such tags in an interrogation zone at the same time. What is needed is a method and apparatus by which this limitation can be overcome.

Brief Summary of the Invention

20   The invention is a method for obtaining digital information from a plurality of radiofrequency-identification tags simultaneously interrogated on a single communication channel within a field of interrogation. The method comprises the steps of activating the plurality of tags, and bitwise interrogating the activated tags for the digital information within the field of interrogation to obtain a bitwise predetermined response while 25 deactivating each of the tags having a different bitwise response than the bitwise predetermined response until all of the information is obtained. As a result, the information is unambiguously obtained from the plurality of tags in the field of interrogation.

In one embodiment the step of bitwise interrogating the activated tags comprises 30 the step of serially bitwise interrogating the activated tags. In another embodiment, bitwise interrogating the activated tags comprises arbitrarily bitwise interrogating the activated tags without repeating an interrogation of any given bit of the digital information.

It is determined when the digital information has been completely interrogated from one of the plurality of tags and the digital information obtained is verified. The method may be restarted anew if verification fails.

In one embodiment the step of bitwise interrogating the activated tags while deactivating each of the tags having a different bitwise response than the bitwise predetermined response comprises the step simultaneously generating a response signal from those of the plurality of tags having the bitwise predetermined response, and deactivating others of the plurality of tags not having the bitwise predetermined response. For example, a command sent to the tags could cause those tags having a 1 stored in the interrogated bit position to send a one back to the reader, or if they had a 0 stored in the interrogated bit position to deactivate themselves so that they would no longer respond to reader interrogation until reactivated by the reader by an AWAKE command.

In another embodiment the step of bitwise interrogating the activated tags while deactivating each of the tags having a different bitwise response than the bitwise predetermined response comprises a first step of generating a response signal from those of the plurality of tags having the bitwise predetermined response. A subsequent step is taken for deactivating others of the plurality of tags not having the bitwise predetermined response when the reader sends out a SLEEP command.

The method further comprises verifying the bitwise response bit by bit from the plurality of tags to reduce error of bitwise communication of the information. Verification is made by consecutive repetition of the bit interrogations and responses until a predetermined degree of consistency is realized. In addition the method further comprises verifying the completed information or entire word from the last remaining activated tag to reduce error of communication of the completed information. Again verification is practiced by a redundant read with a predetermined degree of realized consistency.

After a tag is completely and reliably read the method further comprises isolating the read tag to prevent its continued response to interrogation when unread ones of the plurality of tags are subsequently interrogated. In the illustrated embodiment this is achieved by the reader sending out a command which sets a flag as ISOLATED in the last active tag. Thereafter, only tags in which the flag is set at NOT ISOLATED can be interrogated or set to the AWAKE state.

The method further comprises the step of determining when the digital information has been completely interrogated from one of the plurality of tags and verifying the digital information. the method is are restarted anew if verification fails.

The invention is also an apparatus for performing the above methodologies. The reader and tags include radiofrequency transceivers, memories and programmable or custom logic circuitry for receiving, responding and implementing the commands and operations of the methods just described.

The invention is alternatively defined as a system for communicating with a plurality of tags within a field of interrogation on a single communication frequency, wherein the plurality of tags communicate in response to interrogation during the same time period, wherein each of the plurality of tags can be set in an activated AWAKE state or deactivated into a SLEEP state, wherein each of the tags contains digital information, and wherein each of the tags can be set in two distinguishable states, an ISOLATED state and NOT ISOLATED state. The system comprises a first circuit for setting all of the tags which are in the NOT ISOLATED state into the activated AWAKE state. A second circuit interrogates each bit in the digital information stored within each of the tags in the activated AWAKE state to determine if the interrogated bit has a predetermined logic value, and if so to cause each tag to generate a predetermined response if the bit has the predetermined value and otherwise to place the tag in the SLEEP state. A third circuit bitwise accumulates the predetermined responses and lack of the predetermined responses by bit-by-bit reading the digital information from one of the plurality of tags. A fourth circuit places each tag from which the digital information has been bitwise completely read into the ISOLATED state so that subsequent operation of the second and third circuit reads each unique codification of the digital information contained within each of the plurality of tags within the field of interrogation. Although formally described here as separate circuits, in the actual implementation the same circuitry or portions thereof may operate under software control to perform the separately recited functions.

In one embodiment the second circuit may generate two separate sequential commands to generate the predetermined response from selected ones of the tags and to deactivate other ones of the tags. In another embodiment the second circuit generates a single command to simultaneously generate the predetermined response from selected ones of the tags and to deactivate other ones of the tags.

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Stated still another way the invention is a method for interrogating a plurality of RF/ID tags in a single field of interrogation wherein the RF/ID tags communicate on a single frequency during at least overlapping time periods. The method comprises the steps of bitwise interrogating the plurality of tags to determine if any one of the plurality of tags has a predetermined logic value in a predetermined one of a sequence of bit positions. Each of the tags not having the predetermined logic value in the predetermined one of the sequential bit positions is deactivated. The steps of interrogating and deactivating the plurality tags are repeated until only one tag remains activated. The complete information is then obtained from the only one activated tag. The one activated tag is then isolated after the information is obtained therefrom. Each of the foregoing steps for all tags which are not isolated is repeated until complete information has been read from each of the plurality of tags within the field of interrogation.

Still further the invention is a method for interrogating a plurality of RF/ID tags in a single field of interrogation wherein the RF/ID tags communicate on a single frequency during at least overlapping time periods with a single reader comprising the steps of transmitting a train of synchronization pulses from the reader to the tags. each the synchronization pulse having a predetermined pulse width. t_1. and repeated with a predetermined period. t_2. The reader transmits digital data to the plurality of tags by transmitting a selected plurality of pulses with a predetermined pulse separation of t_3. at a repetition rate with a period of t_2. Digital data is transmitted from the plurality of tags to the reader by selectively transmitting a tag data pulse in a selected half of a tag data frame defined by consecutive synchronization pulses transmitted by the reader.

In one embodiment the step of transmitting a train of synchronization pulses is performed by ceasing the transmission of a signal from the reader to the tags for the predetermined pulse width, t1, and repeating the cessation with the predetermined period. t2. The step of transmitting reader digital data from the reader to the plurality of tags comprises transmitting a selected plurality of synchronization pulses to indicate correspondingly selected logical values. The step of transmitting tag digital data from the plurality of tags to the reader comprises transmitting the tag digital data after the last of the reader digital data transmitted from the reader to the tags. The last synchronization pulse comprising the reader digital data defines a first synchronization pulse which defines

the beginning of the tag data frame. Two of the synchronization pulses define a first and second half of the tag data frame.

The invention as summarized above can be better visualized by turning to the following drawings wherein like elements are referenced by like numerals.

Brief Description of the Drawings

Fig. 1 is a simplified diagram illustrating the situation in which the problem of differentiation between multiple RF/ID tags may arise.

Fig. 2 is a flow diagram illustrating the methodology employed in the reader of Fig. 1.

Fig. 3 is a simplified diagrammatic depiction of the functional circuit blocks in the RF/ID devices and reader of Fig. 1.

Fig. 4a is a diagrammatic waveform of the communication protocol from the reader to the RF/ID devices of Fig. 1 wherein a zero is transmitted.

Fig. 4b is a diagrammatic waveform of the communication protocol from the reader to the RF/ID devices of Fig. 1 wherein a one is transmitted.

Fig. 5 is a diagrammatic waveform of the communication protocol from the RF/ID devices to the reader of Fig. 1.

The invention and its various embodiments may now be understood by turning to the following detailed description.

Detailed Description of the Preferred Embodiments

A method and apparatus for determining the identification number or any other information within a plurality of radiofrequency identification tags within a common field of interrogation utilizes a combination of an isolation state into which the tags may be placed together with bitwise interrogation of the identification number or information followed by selective deactivation. The tags have two binary states or flags, a first state that takes on an AWAKE or SLEEP state in which the tag is activated or deactivated respectively. A second state takes on an ISOLATED or NOT ISOLATED state in which the tag is independently deactivated or activated on that separate state. All tags enter the interrogation field in the AWAKE and NOT ISOLATED states. A first bit in the identification number or information is interrogated of all the tags in the field. If any tag

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responds that the bit is a 1, a 1 is entered into an ID register in a reader and all tags in
which a 0 exists in that bit position are deactivated or put into a SLEEP state. If it should
occur that no tag responds that the interrogated bit position is a 1, then a 0 is placed into
the ID register in the reader. In this case all tags are left activated or in the AWAKE state.

5   The process continues until only one tag remains activated. The last activated tag at this
point has been completely read, it is reread for verification, and is then placed in
ISOLATED state. The process is then begun anew with the remaining NOT ISOLATED
tags until all tags have been read. It should be expressly understood that the value of the
logic state which is queried is arbitrary. For example, it could be just as easily devised to

10   bitwise interrogate for a 0 rather than a 1.

        Fig. 1 illustrates a situation in which a plurality of RF/ID tags 10 are present
within a zone of interrogation 12 at the same time. The tags are associated or connected
with any object desired and may contain any information pertaining to that object as
required. For example, each of the tags 10 may be connected to a biological sample in an

15   automated sampling system so that patient, physician, file, and even analysis results and
histories are loaded on each of the tags, which are permanently connected to the flask, vile,
case, pouch or other container in which the biological sample is carried. An RF/ID reader
14 interrogates the plurality of tags 10 in interrogation field 12 to determine which tags are
present at that time and what information is on each tag 10.

20   In the illustrated method of the invention, a tag 10, when active or powered up,
will exist in one of two states, namely in an AWAKE state in which it responds to
commands issued by reader 14, or in a SLEEP state in which it does not respond to reader
commands. It should be understood that the tag is activated when in the AWAKE state
and is deactivated to the SLEEP state so that the terms, activate/AWAKE and

25   deactivated/SLEEP, may be used interchangeably. In addition to the active or inactive
states, AWAKE and SLEEP, there is subordinate set of states, ISOLATED and NOT-
ISOLATED, which are set in response to reader commands as described below.

        The methodology of the invention uses a combination of these states to extract
unique identification codes or information from each RF/ID tag 10 within interrogation

30   field 12. The method is better understood in connection with the flow diagram of Fig. 2.
In step 16 reader 14 directs all tags 10 to an AWAKE status. In step 18, reader 14 then

directs all tags 10 which are NOT ISOLATED to send a 1 bit. All tags 10 which are ISOLATED are directed at step 20 to go to the SLEEP state.

Starting with the mth bit of the identification number stored within each tag 10, which nominally may be the first or last bit, each tag 10 is directed at step 22 to respond to reader 14 by sending a 1 if the mth bit of the identification number contains a 1. If reader 14 receives any response, then it is known that at least one responding tag 10 contains an identification number with a 1 at the mth bit position. A 1 will then be loaded by reader 14 into a buffer or memory location. It is immaterial whether reader 14 saves the scanned information into a buffer, register or memory location. Any kind of memory device or means for saving the identification code or information may be used by reader 14 and will hereinafter be interchangeably described by any one of them. If no responses are received, then it is known that all tags which are in the AWAKE state have a 0 at this bit position. Reader 14 will then load a 0 into the buffer or memory location for this bit position. If a 1 was received, reader 14 directs the tags with a 0 in the mth position to go to the SLEEP state.

A check is made at step 28 to determine if the complete identification or information scan has been achieved. If the bitwise scan is not complete reader 14 then varies m to the next bit position at step 26 and returns to step 22. The illustrated embodiment describes an incrementation of m from low to high, but there is no requirement that the bit positions be scanned from low to high, from high to low or in any sequential or specific order. The bit positions could be processed in a random order if desired. A check is then made at step 27 to determine if the complete null identification code is received which indicates that the bitwise scan has been completed and that there were no tags 10 in field 12 which were NOT ISOLATED or perhaps even present.

The bitwise interrogation process of steps 22-26 continues until all the bits have been interrogated. At this point, reader 14 will have the identification code of one of the tags in interrogation field 12 loaded into its buffer or memory location, and only this tag is in the AWAKE state. Reader 14 then sets this last tag as ISOLATED in step 30. Steps 16 through 28 are then repeated until all the tags in the field have been identified in this manner.

A specific example will make this clear. Note however that any tag entering the filed of interrogation normally enters in the ASLEEP, NOT ISOLATED state. In Table 1

below, assume there are four tags A-D each having a unique 4-bit identification code as shown in the example of Table I. Assume that the mth bit, the first bit interrogated, is the first or leftmost bit and that the interrogation then continues to the right in Table 1.

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Table 1

Identification Codes in Illustrated Example

Tag	Bit 1	Bit 2	Bit 3	Bit 4
A	1	0	0	1
B	0	1	0	1
C	0	1	1	0
D	1	0	1	1

At step 16, all tags A-D are set to an AWAKE state. Assume for the sake of illustration
10 that one of the tags, tag C, is ISOLATED and that tags A, B, and D are NOT ISOLATED. See Table 3 below for the status of the ISOLATED and NOT ISOLATED flags. Tags A, B, and D are therefore directed by reader 14 to send a 1 at step 18. It is now known that there are NOT ISOLATED tags in interrogation field 12. Reader 14 then directs all the ISOLATED tags, namely tag C, to go asleep at step 20 in Fig. 2 in the first
15 cycle as shown in Table 2.

Table 2

Status of the SLEEP Flag

Tag	cycle 1 step 20	cycle 1 step 24	cycle 1 step 22	cycle 2 step 16	cycle 2 step 24	cycle 3 step 18
A	0	0	1	0	0	1
B	0	1	1	0	1	0
C	1	1	1	1	1	1
D	0	0	0	1	1	1

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Table 3

Status of ISOLATED Flag

Tag	cycle 1	cycle 2	cycle 3	cycle 4
A	0	0	1	1
B	0	0	0	1
C	1	1	1	1
D	0	1	1	1

10   Those tags which are AWAKE, namely tags A, B and D in the example, are now directed
at step 22 to transmit a 1 if the value of the first bit is 1. Thus tags A and D each transmit
a 1. Reader 14 thus places a 1 in the first bit of the identification register 48, since it
knows that there is at least one tag in field 12 having a 1-bit in the first position. Reader
14 at step 24 then directs all tags then in the AWAKE state which have a 0 in the first
15   position, namely tag B, to go to the SLEEP state as shown in Table 2.

There are two tags still in the AWAKE state in field 12, namely tags A and D, as
shown in Table 2. The bit index is incremented at step 26 and then the second bit in the
tags then in the AWAKE state is interrogated. In this case both tags A and D have a 0 in
the second bit position. Since reader 14 receives no response to the interrogation step 22,
20   a 0 is then placed in the second bit position in register 48.

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The bit index is incremented then at step 26 and the third bit interrogated at step 22. In this case, tag D, having a 1 in the third bit position, will return a 1. Reader 14 places a 1 in the third bit position of its register 48 and commands tag A which has a 0 in the third bit position to SLEEP. Tag D is now the only tag within the field still in the AWAKE state and still responding to reader commands as shown in Table 2.

The bit index, m, is again incremented at step 26 and the fourth bit of all tags in the AWAKE state are interrogated, which in this case is only tag D. Since tag D has a 1 in the fourth bit, a 1 is then written into register 48 of reader 14 and tag D has been uniquely identified and its ID code read, although there were three NOT ISOLATED tags in field 12 at the beginning of the scan. Since the identity of one tag is known, reader 14 directs this identifiable tag, tag D, to enter the ISOLATED state as shown in the cycle 2 of Table 3. At this point, only tags A and B remain NOT ISOLATED. The process then returns to step 16 and a second cycle begun.

All NOT ISOLATED tags are again set to the AWAKE step at step 16 and those which are NOT ISOLATED. tags A and B, are left in the AWAKE state while the ISOLATED tags, tags C and D, are put to SLEEP as shown in cycle 2 of Table 2. The index bit, m, has been reset to the first position and the first bit position of the AWAKE tags, tags A and B, interrogated. Thus tag A has a 1 in the first bit position. A 1 is returned by tag A and all tags having a 0 in the first position are directed to SLEEP, at step 24, namely tag B as shown in cycle 2 of Table 2. A 1 is placed in the first position of register 48 in reader 14 corresponding to the cycle 2 identification as shown in Table 4.

Table 4

Identification of AWAKE Tags

cycle 1	1	0	1	1	tag D
cycle 2	1	0	0	1	tag A
cycle 3	0	1	0	1	tag B

The cycle repeats a third time so that the second bit of all AWAKE tags is then interrogated. However, in this case, only tag A is AWAKE as shown in Table 2 and has a 0 in the position, so tag A does not send a 1 back to reader 14 and reader 14 knows that

all tags in the field have a 0 in the second position. A zero is placed in the second bit position in register 48 in cycle 2 as shown in Table 4 and bit index m incremented.

The same situation again occurs and a 0 is placed in the third position finally followed by interrogation in the fourth position of tag A where a 1 is returned and the complete identification code of tag A known. At this point in step 28 tag A is then ISOLATED and control again returned to step 16 for the beginning of cycle 3.

As before in the first step of cycle 3 all the ISOLATED tags, A, C and D are put to SLEEP with only tag B remaining AWAKE. When the first bit position is interrogated, tag B does not respond and reader 14 places a 0 in the first position. Bit index, m then is incremented and second bit position interrogated with tag B returning to 1 causing reader 14 to place a 1 in the second bit position. A signal is sent out by reader 14 to place all other NOT ISOLATED tags having a 0 in the second position to SLEEP. However, in the case of the last tag the only remaining tag has a 1 in the second bit position and therefore remains in the AWAKE state.

The process continues by interrogating a third bit of tag B, which makes no response and therefore sets a 0 in the third position in identification register 48 in reader 14. Finally the fourth bit is interrogated and returns a 1 which allows reader 14 to uniquely identify tag B.

Once again at step 28 at the beginning of cycle 4, tag B is then set at in an ISOLATED state and all NOT ISOLATED tags are directed AWAKE, however there are none. At this point when reader 14 interrogates each bit position no response will be obtained and a 0000 or null tag identification is returned. This tag identification is reserved code to indicate a null return and indicates to reader 14 there are no further tags in field 12 which have not been read during the previous cycle or at some earlier time.

The ISOLATED/NOT ISOLATED bit flag can then be reset at any other later time should tags 10 again need to be read. The process described in connection with Figs. 1 and 2 in Tables 1-4 reads each tag identification which is unique in field 12. If the identification number and plurality of tags 10 is not unique among the tags, then the methodology identifies the unique sets of identification numbers of tags 10 within field 12. This feature may be used, for example, to identify classes or types of tags present in field 12 where individual identification may not be necessary.

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Any circuit architecture or organization now known or later devised capable of performing the essential method of Fig. 2 can be used. The illustrated embodiment described below is only provided for the purpose of a single example. In the highly diagrammatic view of Fig. 3, each tag 10 includes an antenna or other receiving element 32

5   coupled to a transceiver circuit 34. Transceiver circuit 34 may include any type of communication and signal conditioning circuitry now known or later devised to perform the functions needed in the situation. Transceiver 34 is coupled to a microprocessor 36, which has among other components at least two memories or a memory with at least two addressable locations, one memory or memory location 38 for holding two flags, namely

10   AWAKE/SLEEP and NOT-ISOLATED/ISOLATED. A second memory or location 40 holds the identification number of tag 10 or other information particular to tag 10.

Reader 14 similarly includes an antenna 42 also coupled to a transceiver 44 and includes any necessary communication or signal conditioning circuitry now known or later devised as may be required in the situation. Transceiver 44 is coupled to a microprocessor

15   46 which includes at least one register, buffer, memory or memory location 48 at least as large as memory or memory location 40 in which location 48 the information stored in memory or memory location 40 is reassembled in memory or memory location 48 according to the method described above. Conventional software is stored within microprocessors 36 and 46 for implementing the methodology shown in Fig. 2 and

20   illustrated in connection with Tables 1-4.

Many modifications may be made in the process without changing the basic principle of bit-by-bit search. For example, the AWAKE command of step 16 can be skipped if alternate commands are available between reader 14 and tags 10. For example, it has been assumed in the illustrated embodiment that steps 18 and 20 would have to be

25   separate commands from reader 14 in order to be implemented in tags 10. It is also possible that a single command could be devised for tags 10 which would cause them to send a 1 if NOT ISOLATED and otherwise to go to SLEEP if ISOLATED. Therefore, it can be understood that the number of commands which must be issued by reader 14 can be varied according to the design of the instructions set of the system without departing from

30   the spirit and scope of the invention. Therefore, it is to be expressly understood that the methodology is not based on any specific instructions set or any particular communication protocol.

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Further, the methodology can be adapted to identify which tags enter the field during the course of the search and to provide an error rate verification. For example, after a tag has been identified, reader 14 can issue a verification command interrogating the full identification number of any tag then remaining AWAKE, which at the end of the

5   search process will be the single uniquely identified tag. The last remaining AWAKE tag can then send its full ID number and reader 14 can compare it to what has been determined according to the search. This verification can be repeated a number of times until it is reliably determined that there is a match or not with the bit-wise search. If ultimately it is determined that there is no match, then it can be concluded that either there was an error in

10   the communication, as might occur in a noisy field, or that the originally identified tag has permanently left field 12 before reliable verification could be established, or that a new tag entered verification field 12 after the search had begun to identify a previously present tag.

A new entry can always be determined because in the latter case, there will be a conflict of communication when a new NOT ISOLATED tag enters the field and responds

15   to a general verification tag query. Reader 14 will then likely obtain both ones and zeroes transmitted during the same bit positions. In either case, the tag identification can be deleted and the search restarted until unique tag identification and verification has been obtained.

Further, error rate communication can be assisted by redundant communication of

20   the bitwise communications in Fig. 2. For example, each bit can be transmitted a multiplicity of times and only accepted if a sufficient number of the bitwise communications are identical. If bitwise communication is not reliable either because of a noisy environment or because of high rate of change of tags 10 entering and leaving field 12, the search can be terminated and repeatedly restarted until reliable identification is

25   obtained or timed out.

It should further be noted that the methodology of the invention can be applied to any number of groups of numbers contained within tags 10 and need not per se be used only for identification code. For example, it may be of interest in some applications not to know the particular identity of the tags, but whether any of the tags contain certain kinds

30   of information. Information in specified bit positions can be searched to determine if certain type of content was stored in the tag. Statistical measures could then be taken of tags in the field of their historical content by utilizing the methodology once to identify the

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content parameter and a second time to identify the identity of the tags having the determined content value.

The communications protocol between reader 14 and tags 10 is based on a series of pulses generated by reader 14 used to synchronize the communication with tags 10. A pulse is defined in this context to be a cessation of transmission by reader 14 for a predefined period of time, t_1. This pulse is detected by tags 10 as a loss of signal for a time, t_1. The signaling sequence is based on the direction of communication, i.e. reader to tag or vice versa, as well as being synchronized with the rf signal of reader 14. Reader 14 transmits or communicates continuously with tags 10 and periodically ceases for the pulses, t_1. The loss of signal is repeated periodically every t_2 microseconds. The periodic loss is the synchronization signal or pattern by which communications between reader 14 and tags 10 is ruled.

Reader 14 augments the periodic synchronization signal to communicate a bit string to tags 10 as follows. A "zero" is created by sending two synchronization pulses separated by a time gap, t_3, as shown in Fig. 4a. A "one" is created by sending three synchronization pulses separated by a time gap, t_3, as shown in Fig. 4b. Information is therefore sent from reader 14 to tags 10 using a series of ones and zeroes based on this pulsing which is diagrammatically illustrated in Figs. 4a and b. An approximate data bit transfer rate of $1/t_2$ is thus realized.

In the communication from tags 10 to reader 14 the last data bit from reader 14 establishes the start 100 of a tag data frame 102. Each tag data frame 102 is measured as two reader defined synchronization periods 104. Tags 10 communicate data back to reader 14 by sending a reflected signal of duration t_1 in the appropriate segment of tag data frame 102 as illustrated in Fig. 5. A "one" is communicated as a return pulse in the first half of tag data frame 102 and a "zero" is communicated as a return pulse in the second half of tag data frame 102. Tags 10 return their data to reader 14, one bit in each tag data frame 102 until all data has been transmitted.

This communications protocol has the advantage that multiple responding tags 10 can be detected as long as their data differs. For example, assuming that each tag 10 has a unique identification number or stored digital information, there will be at least one bit stored in any two tags in which different values are different. Sooner or later one tag 10 will transmit a one and another will transmit a zero. This means that within some tag data

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frame 102 reader 14 will detect a bit in each half frame indicating that there are two or more responding tags in the field of interrogation. Although the data cannot be separated by reader 14 among a plurality of tags 10, reader 14 is aware that two or more tags 10 are active. After a first pass ID register 48 will be full and there should be only one tag 10 still active. All the bits, the word, of that tag are then reread and if at any bit position multiple tags are detected, then either there is an error in the communication or a new unread tag has entered the field of interrogation after the read and isolate process was initially begun. This word can be reread multiple times to insure that error has occurred. Upon the occurrence of a verified error register 48 is cleared, all tags 10 set AWAKE and NOT ISOLATED, and the process is then restarted anew.

Many alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. Therefore, it must be understood that the illustrated embodiment has been set forth only for the purposes of example and that it should not be taken as limiting the invention as defined by the following claims.

The words used in this specification to describe the invention and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification structure, material or acts beyond the scope of the commonly defined meanings. Thus if an element can be understood in the context of this specification as including more than one meaning, then its use in a claim must be understood as being generic to all possible meanings supported by the specification and by the word itself.

The definitions of the words or elements of the following claims are, therefore, defined in this specification to include not only the combination of elements which are literally set forth, but all equivalent structure, material or acts for performing substantially the same function in substantially the same way to obtain substantially the same result.

Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements.

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The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptionally equivalent, what can be obviously substituted and also what essentially incorporates the essential idea of the invention.

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We claim

1   1.   A method for obtaining digital information from a plurality of
2 radiofrequency-identification tags simultaneously interrogated on a single
3 communication channel within a field of interrogation comprising:
4   activating said plurality of tags; and
5   bitwise interrogating said activated tags for said digital information within
6 said field of interrogation to obtain a bitwise predetermined response while
7 deactivating each of said tags having a different bitwise response than said bitwise
8 predetermined response until all of said information is obtained,
9   whereby said information is unambiguously obtained from said plurality of
10 tags in said field of interrogation.

1   2.   The method of Claim 1 where bitwise interrogating said
2 activated tags comprises serially bitwise interrogating said activated tags.

1   3.   The method of Claim 1 where bitwise interrogating said
2 activated tags comprises arbitrarily bitwise interrogating said activated tags without
3 repeating an interrogation of any given bit of said digital information.

1   4.   The method of Claim 1 further comprising determining when
2 said digital information has been completely interrogated from one of said plurality
3 of tags and verifying said digital information, said method being restarted anew if
4 verification fails.

1   5.   The method of Claim 1 where bitwise interrogating said
2 activated tags while deactivating each of said tags having a different bitwise
3 response than said bitwise predetermined response comprises simultaneously
4 generating a response signal from those of said plurality of tags having said bitwise
5 predetermined response, and deactivating others of said plurality of tags not having
6 said bitwise predetermined response.

1   6.   The method of Claim 1 where bitwise interrogating said

2 activated tags while deactivating each of said tags having a different bitwise

3 response than said bitwise predetermined response comprises first generating a

4 response signal from those of said plurality of tags having said bitwise

5 predetermined response, and second deactivating others of said plurality of tags not

6 having said bitwise predetermined response.

1   7.   The method of Claim 1 further comprising verifying said

2 bitwise response from said plurality of tags to reduce error of bitwise communication

3 of said information.

1   8.   The method of Claim 1 further comprising verifying said

2 completed information from said tag to reduce error of communication of said

3 completed information.

1   9.   The method of Claim 1 further comprising isolating each of

2 said tags when said digital information is completely read from said tag to prevent

3 its continued response to interrogation from said read tag when unread ones of said

4 plurality of tags are subsequently interrogated.

1   10.   The method of Claim 9 further comprising determining when

2 said digital information has been completely interrogated from one of said plurality

3 of tags and verifying said digital information, said method being restarted anew if

4 verification fails.

1   11.   An apparatus for obtaining digital information from a plurality

2 of radiofrequency-identification tags simultaneously interrogated on a single

3 communication channel within a field of interrogation comprising:

4   means for activating said plurality of tags; and

5   means for bitwise interrogating said activated tags for said digital

6 information within said field of interrogation to obtain a bitwise predetermined

7   response while deactivating each of said tags having a different bitwise response

8   than said bitwise predetermined response until all of said information is obtained,

9   whereby said information is unambiguously obtained from said plurality of

10 tags in said field of interrogation.

1   12.   The apparatus of Claim 11 where said means for bitwise

2   interrogating said activated tags comprises means for serially bitwise interrogating

3   said activated tags.

1   13.   The apparatus of Claim 11 where said means for bitwise

2   interrogating said activated tags comprises means for arbitrarily bitwise

3   interrogating said activated tags without repeating an interrogation of any given bit

4   of said digital information.

1   14.   The apparatus of Claim 11 further comprising means for

2   determining when said digital information has been completely interrogated from

3   one of said plurality of tags and for verifying said digital information, said means for

4   bitwise interrogating said activated tags being restarted anew if verification fails.

1   15.   The apparatus of Claim 11 where said means for bitwise

2   interrogating said activated tags while deactivating each of said tags having a

3   different bitwise response than said bitwise predetermined response comprises

4   means for simultaneously generating a response signal from those of said plurality of

5   tags having said bitwise predetermined response, and for deactivating others of said

6   plurality of tags not having said bitwise predetermined response.

1   16.   The apparatus of Claim 1 where said means for bitwise

2   interrogating said activated tags while deactivating each of said tags having a

3   different bitwise response than said bitwise predetermined response comprises first

4   means for generating a response signal from those of said plurality of tags having

5   said bitwise predetermined response, and second means for subsequently

6   deactivating others of said plurality of tags not having said bitwise predetermined

7   response.

1   17.   The apparatus of Claim 11 further comprising means for

2   verifying said bitwise response from said plurality of tags to reduce error of bitwise

3   communication of said information.

1   18.   The apparatus of Claim 11 further comprising means for

2   verifying said completed information from said tag to reduce error of

3   communication of said completed information.

1   19.   The apparatus of Claim 11 further comprising means for

2   isolating each of said tags when said digital information is completely read from said

3   tag to prevent its continued response to interrogation from said read tag when

4   unread ones of said plurality of tags are subsequently interrogated.

1   20.   A system for communicating with a plurality of tags within a

2   field of interrogation on a single communication frequency wherein said plurality of

3   tags communicate in response to interrogation during said same time period,

4   wherein each of said plurality of tags can be set in an activated AWAKE state or

5   deactivated into a SLEEP state, wherein each of said tags contains digital

6   information, and wherein each of said tags can be set in two distinguishable states,

7   an ISOLATED state and NOT ISOLATED state, said system comprising:

8   first means for setting all of said tags which are in said NOT ISOLATED

9   state into said activated AWAKE state;

10   second means for interrogating each bit in said digital information stored

11   within each of said tags in said activated AWAKE state to determine if said

12   interrogated bit has a predetermined logic value, and if so to cause each tag to

13   generate a predetermined response if said bit has said predetermined value and

14   otherwise to place said tag in said SLEEP state;

15   third means for bitwise accumulating said predetermined responses and lack
16   of said predetermined responses by bit-by-bit reading said digital information from
17   one of said plurality of tags; and

18   fourth means for placing each said tag from which said digital information
19   has been bitwise completely read into said ISOLATED state so that subsequent
20   operation of said second and third means reads each unique codification of said
21   digital information contained within each of said plurality of tags within said field of
22   interrogation.

1   21.   The system of Claim 20 where said second means generates two
2   separate sequential commands to generate said predetermined response from
3   selected ones of said tags and to deactivate other ones of said tags.

1   22.   The system of Claim 20 where said second means generates a
2   single command to simultaneously generate said predetermined response from
3   selected ones of said tags and to deactivate other ones of said tags.

1   23.   A method for interrogating a plurality of RF/ID tags in a single
2   field of interrogation wherein said RF/ID tags communicate on a single frequency
3   during at least overlapping time periods comprising the steps of:
4   bitwise interrogating said plurality of tags to determine if any one of said
5   plurality of tags has a predetermined logic value in a predetermined one of a
6   sequence of bit positions;
7   deactivating each of said tags not having said predetermined logic value in
8   said predetermined one of said sequential bit positions;
9   repeating said steps of interrogating and deactivating said plurality tags until
10   only one tag remains activated;
11   obtaining information from said only one activated tag;
12   isolating said one activated tag after said information is obtained therefrom;
13   and

14   repeating each of said foregoing steps for all tags not isolated until complete

15   information has been read from each of said plurality of tags within said field of

16   interrogation.

1   24.   A method for interrogating a plurality of RF/ID tags in a single

2   field of interrogation wherein said RF/ID tags communicate on a single frequency

3   during at least overlapping time periods with a single reader comprising the steps of:

4   transmitting a train of synchronization pulses from said reader to said tags,

5   each said synchronization pulse having a predetermined pulse width, t_1, and

6   repeated with a predetermined period, t_2;

7   transmitting reader digital data from said reader to said plurality of tags by

8   transmitting a selected plurality of pulses with a predetermined pulse separation of

9   t_3, at a repetition rate with a period of t_2; and

10   transmitting digital data from said plurality of tags to said reader by

11   selectively transmitting a tag data pulse in a selected half of a tag data frame defined

12   by consecutive synchronization pulses transmitted by said reader.

1   25.   The method of Claim 24 wherein transmitting a train of

2   synchronization pulses is defined by ceasing the transmission of a signal from said

3   reader to said tags for said predetermined pulse width, t_1, and repeating said

4   cessation with said predetermined period, t_2.

1   26.   The method of Claim 24 wherein transmitting reader digital

2   data from said reader to said plurality of tags comprises transmitting a selected

3   plurality of synchronization pulses to indicate correspondingly selected logical

4   values.

1   27.   The method of Claim 26 wherein transmitting tag digital data

2   from said plurality of tags to said reader comprises transmitting said tag digital data

3   after the last of said reader digital data transmitted from said reader to said tags,

4   said last synchronization pulse comprising said reader digital data defining a first

5   synchronization pulse defining the beginning of said tag data frame, two of said

6   synchronization pulses defining a first and second half of said tag data frame.

FIG. 1
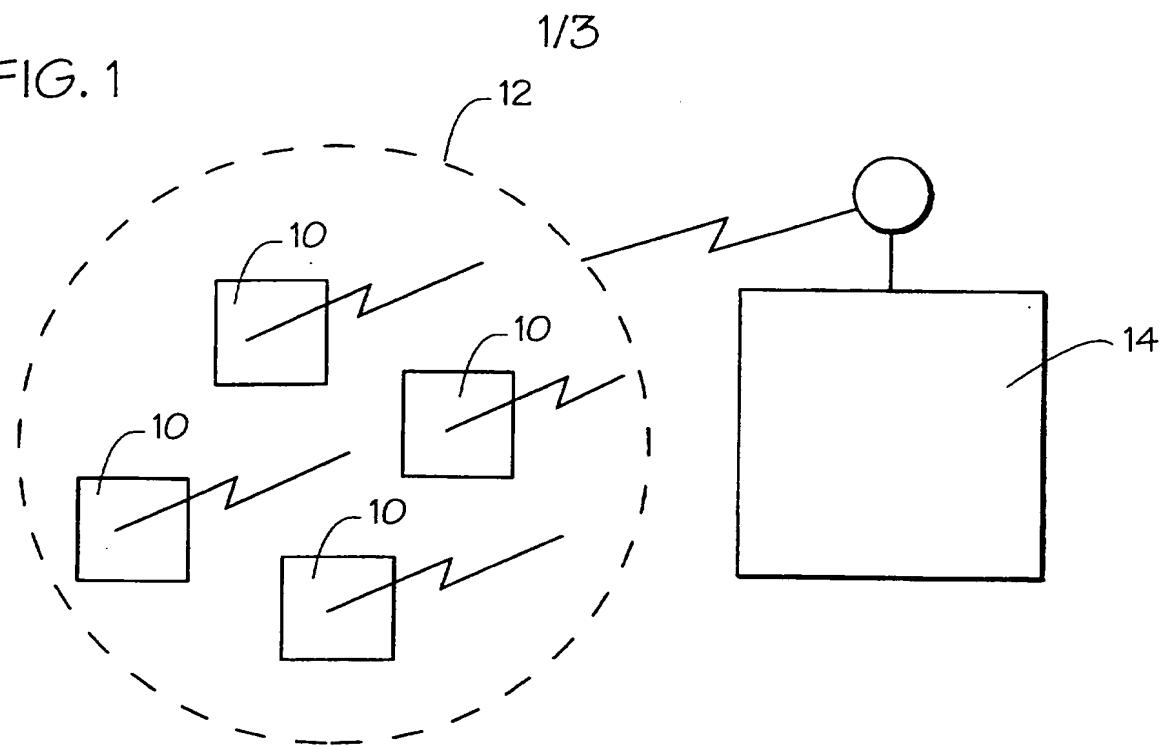
FIG. 3
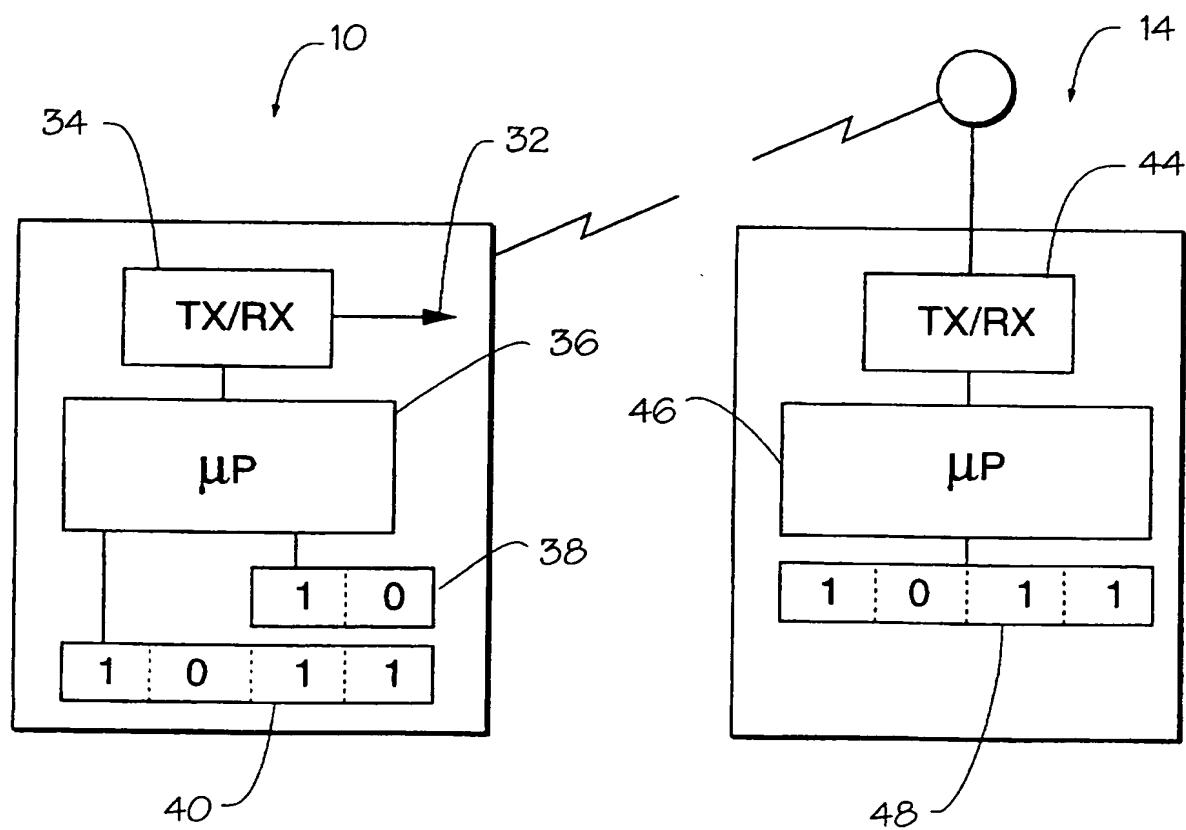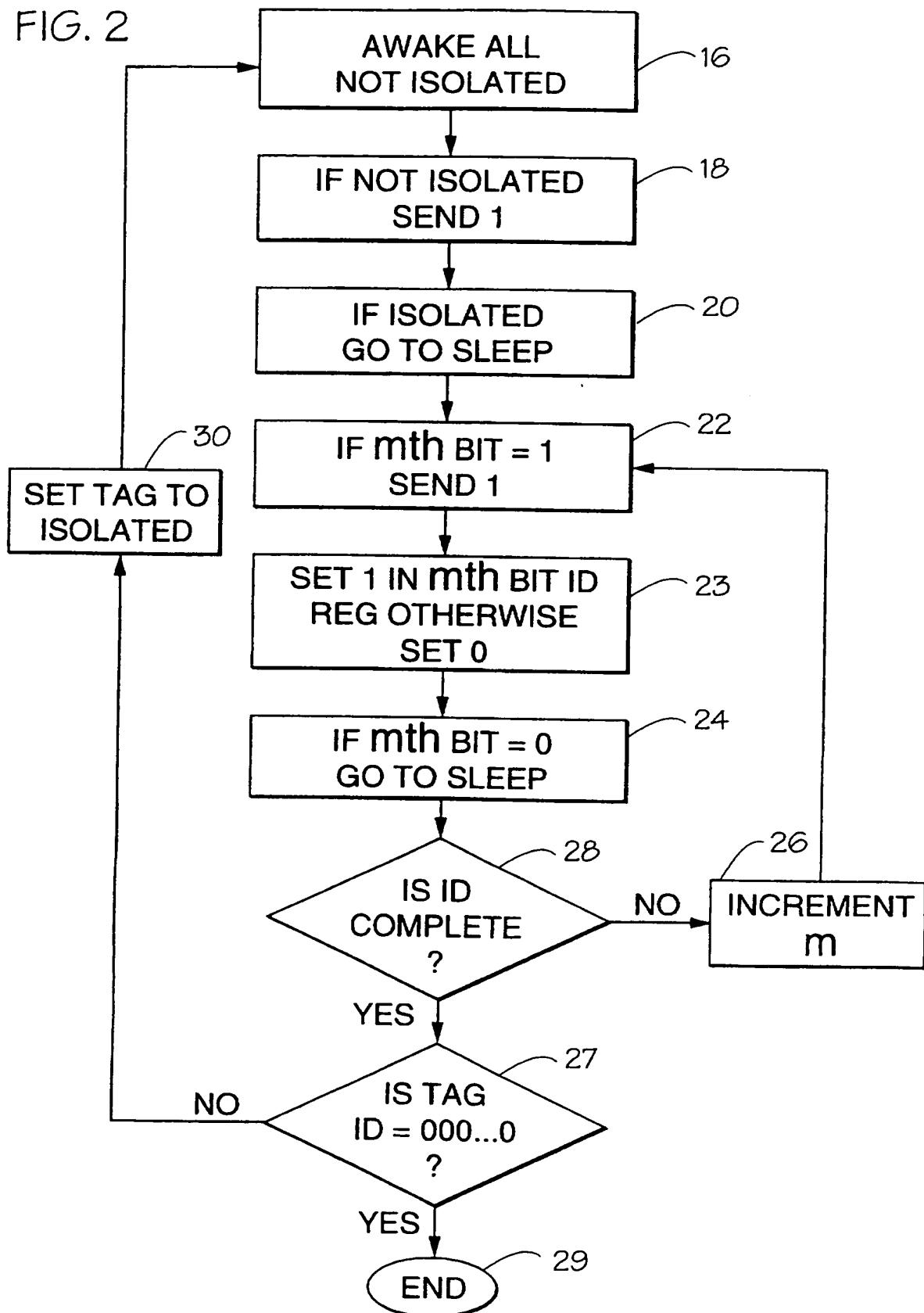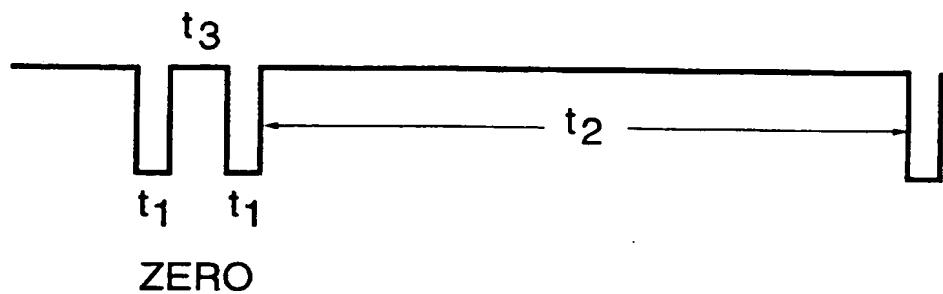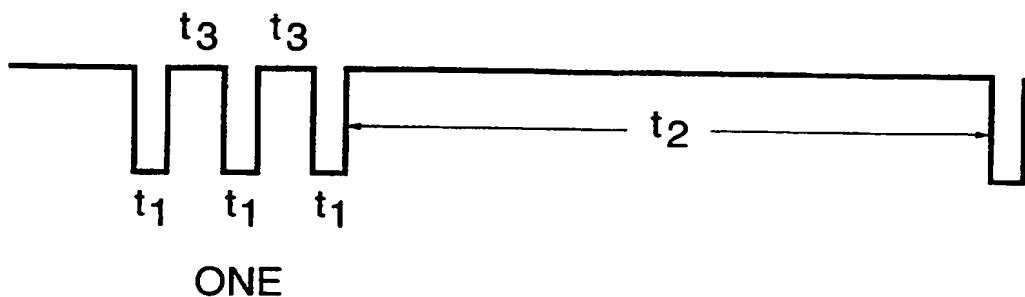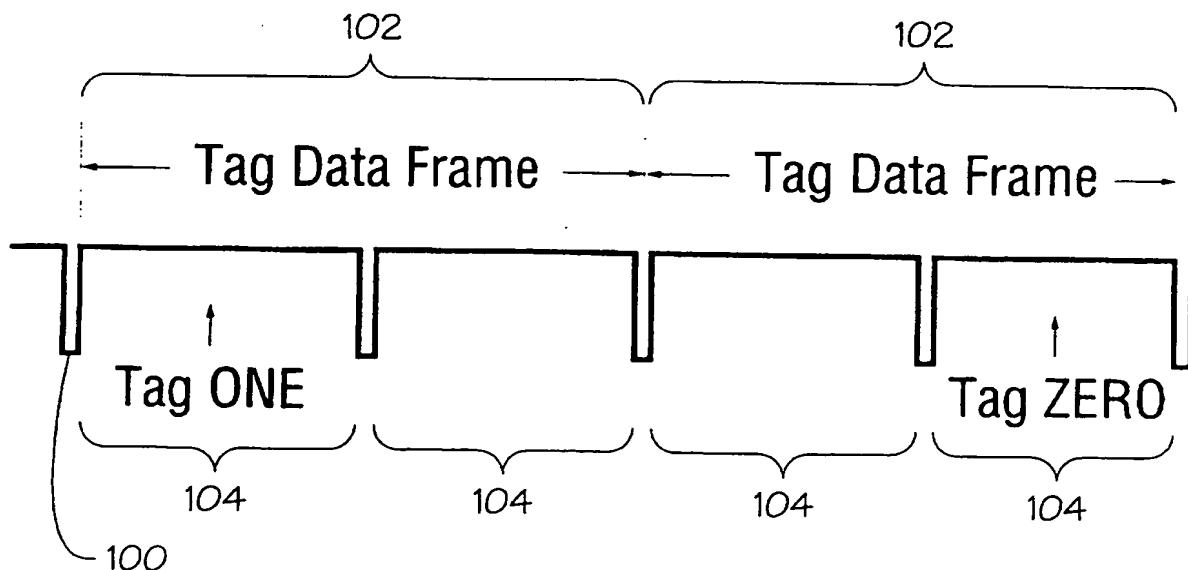
FIG. 2

AWAKE ALL
NOT ISOLATED — 16

IF NOT ISOLATED
SEND 1 — 18

IF ISOLATED
GO TO SLEEP — 20

IF mth BIT = 1
SEND 1 — 22

SET 1 IN mth BIT ID
REG OTHERWISE
SET 0 — 23

IF mth BIT = 0
GO TO SLEEP — 24

30 — SET TAG TO
ISOLATED

IS ID
COMPLETE
? — 28

NO → INCREMENT
m — 26

YES

IS TAG
ID = 000...0
? — 27

NO

YES

END — 29

FIG. 4a

ZERO

FIG. 4b

ONE

FIG. 5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6)   :G06F 7/04; G11C 17/16
US CL   :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. :   340/825.31, 825.34, 825.54, 825.02, 825.08; 365/225.7; 235/380; 327/525

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS messenger
search terms: RFID TAG# AND LOGIC VALUE#, TAG# AND INTERROGATION FIELD; DEACTIVAT?, SYNCHRONIZATION PULSE#, COMMUNICATION ERROR

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,339,073 A (DODD et al.) 16 August 1994, Abstract and summary, Figs. 1A, 1B, 4-6, col. 2, lines 10-19, col. 3, lines 47-49, col. 4, lines 13-24, and col. 6, lines 5-52 and 61-65.	1-19, 23 ------------ 20-22, 24-27
Y, P	US 5,583,819 A (ROESNER et al.) 10 December 1996, Title, Abstract, and Summary, Figs. 7 and 8, col. 8, lines 9-28 and col. 13, line 42 to column 14, line 22.	24-27

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed

"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 JUNE 1997	2 5 JUL 1997

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer YONEL BEAULIEU
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Form PCT/ISA/210 (second sheet)(July 1992)*

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

340/825.31, 825.34, 825.54, 825.02, 825.08; 365/225.7; 235/380; 327/525